Gas House
Delaware, Lackawanna & Western Railroad
Scranton
Lackawanna County
Pennsylvania

HAER No. PA-132G

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Historic American Engineering Record
National Park Service
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HISTORIC AMERICAN ENGINEERING RECORD

Delaware, Lackawanna & Western Railroad: Scranton Yards Gas House

HAER NO. PA-132G

LOCATION: 100 block of South Washington Avenue, West Side Scranton, Lackawanna County, Pennsylvania

UTM: 18/44412/458367
QUAD: Scranton

DATE OF CONSTRUCTION: 1909

ENGINEER/ ARCHITECT:

CONTRACTOR: Delaware, Lackawanna & Western Railroad

PRESENT OWNER: United States Department of the Interior, National Park Service

PRESENT USE: Not in use.

SIGNIFICANCE: The gas house of the Scranton yards of the D,L & W was built to supply fuel to the foundries and furnaces of the 1909 locomotive shops at the site. The gas house produced water gas, not widely used in U.S. industry, from the company's own supplies of anthracite.

HISTORIANS: Amy Slaton and Kathryn Steen
Delaware, Lackawanna & Western Railroad: Scranton Yards Recording Project, 1989

INTRODUCTION

The locomotive shops built by the Delaware, Lackawanna & Western Railroad in Scranton in 1909 were supplied with water gas, a hot, even-burning artificial gas that was manufactured on site by the D,L & W from its own supplies of anthracite. The gas house, which was put into operation in 1910, stood on the west side of Washington Avenue, across the street from the foundries, furnaces, machine shops and other facilities that consumed its product. Though water gas had been used by industries in the U.S. and Germany for almost 50 years by that point, oil was the most common furnace fuel, and the employment of water gas by the D,L & W shops was somewhat risky. Because it was to be produced "in-house," rather than purchased from an outside supplier, the D,L & W's production of water gas required a large initial investment in a physical plant. Further, the locomotive blacksmith and machine shops were vital to the operation of the Scranton mainline, and the functioning of the shops would depend solely on the performance of the gas house--a relatively small utility plant.[1] A year after the gas house opened it was declared a success, having provided a dependable source of efficient and economical fuel that was well-received by the shop workers who used it.[2]

D,L & W USE OF WATER GAS

Water gas is a variant of producer gas, a fuel manufactured by the partial burning of carbonaceous materials like coal or coke. Producer gas had its origins in Germany in the 1830s, when Karl G. Bischof introduced an internally fired gas producer and burned the resultant gas in furnaces.[3] Several engineers have been credited with introducing steam into the producer gas process: David D. Gaillard, and du Motay and Lowe are cited as having invented water gas sometime between 1847 and 1873.[4] Water gas burned at a higher temperature than producer gas, and its efficiency was enhanced further when regenerative furnaces that reused waste gases, developed by K.W. Siemens of England in the 1860s, were combined with gas production.[5] By the time the D,L & W was ready to design their new locomotive shops at Scranton in the first years of the twentieth century, the use of water gas for open hearth and crucible steel making, annealing, brazing, tempering, soldering and other kinds of metallurgical work had been developed, if not widely established, in the U.S.[6]

The gas house's output was consumed primarily by the blacksmith shops in such varied tasks as case hardening, tool dressing, and operating steam hammers, drop hammers and spring makers. The larger furnaces in the blacksmith shop were manufactured by Rockwell Furnace Co., and the smaller furnaces by the American Gas Machine Co. The furnaces were adjusted over their first year or so of use to achieve greatest efficiency.[7] One significant aspect of the original installation was the provision of pipes set inside hot waste gas flues. The water gas flowed through these pipes on its way to the furnaces' beds, and was thus preheated to 400-500 degrees Fahrenheit, effecting substantial savings in time and fuel consumption.[8] The furnaces were estimated to have run at about 2,750-2,800 degrees Fahrenheit. One example of their rate of heating was recorded in 1912: "A 250-lb pile of metal can be raised to a welding heat ready for the hammer in from 40 to 50 minutes, the record for the furnace being nine heats of nine piles each in a day of ten hours." [9]

In the foundries of the locomotive shops, gas was used in core ovens and brass furnaces. It was probably also used in the foundry's "cupolas," in which certain types of scrap metal for the yards and shops could be melted for recasting.[10] Some of these furnaces were fitted with two burners, allowing careful control of the amount of heat in use. In the boiler and machine shops, water gas was used for rivet heating. This frequent, small-scale operation was facilitated by the placement of gas hose connections at regular intervals along shop walls and columns. The water gas was also piped to the electrical department for making babbitt metal (a soft alloy usually used in bearings) and heating soldering iron, to the pipe shop for bending pipe, and to the laboratory (at which most of the D,L & W's materials testing was done) for all heating purposes.[11]

ADVANTAGES OF WATER GAS

The advantages of using water gas rather than oil for metallurgical work were manifold. Of primary importance in the case of the D,L & W was their handy, inexpensive supply of anthracite. Estimates of 1912 show that the blacksmith shops operated with gas at a cost of $17.62 per day, where fuel oil would have cost $29.32. The brass furnaces of the foundry showed a cost of $1.42 per day, versus $3.52 if operated with oil.[12] It should be noted that water gas, like other producer gases, burned with very minor loss of heat (unlike solid fuels, it burned with the addition of little extra air, so very little sensible heat was carried off in waste; its efficiency at the D,L & W shops was further increased by the recirculation of escaping gases[13]). Water gas is particularly easy to regulate, and many types of metal work require rapid and subtle changes in temperature.[14] Water gas also heats more rapidly than oil, though not so quickly that the material being heated achieves too great a temperature on the outside before heating on the inside.[15] Finally, gas is more easily transportable than solid fuels. Pipes at the D,L & W installation ran through the locomotive shop complex in subway tunnels, leaving shop floors unobstructed. One disadvantage to water gas is that it is highly toxic, and undetectable, to humans. It is possible that the D,L & W followed the European practice of "flavoring" their gas for easy detection by passing it through foul smelling solutions.[16]

THE GAS HOUSE: LOCATION AND STRUCTURE

The gas house itself was a simple two-story concrete building. In addition to space for three gas generators (two were built with the original building and a third sometime after 1915[17]), the building had space for the three to five workers needed on any shift to move about the machinery. (Two of these workers were part-time laborers who periodically emptied ashes from the gas producing equipment, one was a supervising foreman, and the total cost of the plant in labor for one day was established in 1912 at probably around $5.00.[18]) Ashes were removed by way of a conveyor that carried them from the generator floor up to waiting hopper cars outside. It was from these tracks, positioned above the gas house machinery, that coal was automatically loaded by gravity into the building. With the subway--through which steam pipes from the D,L & W's power house entered the gas house--and the 20-inch gas main that ran from the gas house's holding tanks to the shops, these tracks constituted the gas house's connections to the rest of the D,L & W yards. Such streamlined traffic patterns were characteristic of construction done during the Truesdale administration (1899-1925): the gas house's location was convenient to the facilities it served and those that serviced it.

The gas house was designed by architect Frank J. Nies under the supervision of chief engineer Lincoln Bush. The cast-in-place column-and-beam reinforced concrete construction allowed the placement of large windows on the west, south, and east sides of the building, an approach that followed the pioneering turn-of-the-century "factory style" concrete architecture of Ernest L. Ransome.[19] The D,L & W had first used concrete in its Newark, New Jersey grade crossing eliminations of 1902. Under Lincoln Bush, chief engineer of the D,L & W from 1903 to 1909, the floors, subways, and foundations of the railroad's Keyser Valley and Kingston shops were constructed of concrete slabs, and in 1906 the D,L & W first used reinforced concrete in building a coal trestle in Hoboken. By the time the Scranton Locomotive Shops were built in 1909, the company was committed to exhaustive testing and inspection of its concrete materials, and had acquired the nickname, "The Reinforced Concrete Railroad." [20] The shop complex buildings, of which the gas house was one, are almost all of concrete skeleton and slab construction. The north side of the gas house was set against a large concrete counterfort abutment in which were set the coal hoppers that supplied the gas producing machinery. Clerestory windows were placed at the top of the north wall. A monitor ran the length of the building to provide additional light and ventilation.

The simple squared-off shape of the gas house is much like the contours of many other D,L & W structures. Its surface, however, is uniform in color and texture, with the evidence of its wood formwork still apparent. In these respects it is unlike the rather domestic looking concrete signal towers and stations that Nies designed for the railroad and also unlike the other locomotive shop buildings of 1909, which have brick infill, cladding and corbelling, and some simple detailing in their bases and eves. The gas house resembles the oil house of 1911 built toward the western end of the Scranton Yards. Like this small, unesthetic concrete shed, the gas house was a supply structure. Besides the simple articulation where the walls meet the slightly thicker base, and the minimal variety afforded by pre-fabricated metal window frames, there is little about the gas house's architectural vocabulary that does not exceed the almost purely utilitarian. Unlike the oil house, however, the gas house did face a public thoroughfare, and, as in the case of the other shop complex buildings, its function is announced in large, inset letters that face the street.

Today, the gas house is intact but derelict. It was used as a machine shop in the diesel era of the 1950s and '60s, during which time all gas production equipment was removed, and the coal hoppers covered over. Though the use of water gas for fuel was somewhat unusual in 1909, the historical significance of the gas house resides primarily in how extensively it utilized the D,L & W's own raw material (anthracite) in the company's locomotive shops.

THE PRODUCTION OF WATER GAS

In the production of the water gas at the Scranton shops, there were essentially four steps: 1) the gas was produced in the generators, 2) given a first cleaning in the wet scrubber, 3) subjected to a second cleaning in the dry scrubber, and 4) sent to the gas holder to await use.

The generators in the gas house were the heart of the gas-producing operation. In the generators, steam passed through a burning bed of coal, combined with the coal's carbon, and emerged as water gas. The name "water gas" was derived from the use of steam in the production process. Each generator was a 15-foot-high cylinder with an outside diameter of 10 feet. Inside, the generators' walls were lined with 13½ inches of firebrick to help retain heat. At the base of a generator, on the inside, there was an arch of firebrick to support the fire. Two steam lines connected to the generator on the side, one near the top and one near the bottom.[21]

Coal for the generators' fires arrived by railroad car. The gas house was built at the bottom of a hill such that railroad tracks ran along the top of the building on its north side. Under the tracks coal pockets received the anthracite from bottom dumping coal cars. The coal flowed down retractable spouts on the building's second story, and poured into the generators on the first floor through holes in the second story floor.[22] The coal bed filled most of the interior of each generator.

The fire in the coal bed had to maintain a temperature of at least 1,832 degrees Fahrenheit to provoke the desired chemical reactions.[23] To raise the temperature of the bed, air was blasted up from the bottom. Any incidental gases created during the air blast constituted waste, and were vented out of the top of the gas house through a flue. When the fire was sufficiently hot, steam from the lower steam valve was sent through the bed of coal, exiting out of the top of the generator to the wet scrubber. The chemical reactions that occurred in producing the gas absorbed heat--the reactions were "endothermic"--and after a ten-minute steam blast, the fire would have cooled to a point where the reactions were no longer taking place. At this point, the operators gave the coal bed another five-minute blast of air. When the temperature of the bed rose again, the steam valve at the top of the generator was opened and the gas was formed in a "downdraft" and left the generator at its base. Alternating the "downdrafts" and "updrafts" prevented the fire in the coal bed from leaving the bottom of the bed.[24]

When the steam (H_2O) hit the coal bed, the heat separated the steam into its elements: hydrogen (H) and oxygen (O). The two separate elements then combined with the carbon (C) of the coal. Two possible reactions could have occurred at this point. One, requiring more heat than the other, was as follows:

$$C + H_2O = H_2 + CO - 29 \text{ calories.}$$

In this case, the coal and steam elements were directly converted into the two main components of water gas: hydrogen (H) and carbon monoxide (CO). This reaction absorbed 29 calories of heat. In the second case, there was a two-stage reaction. First,

$$C + 2H_2O = 2H_2 + CO_2 - 19 \text{ calories}$$

and then

$$CO_2 + H_2 = CO + H_2O - 10 \text{ calories.}$$

This second reaction began and ended at the same place as the first, but had an intermediate stage where carbon dioxide (CO_2) existed.[25]

From the generator, the gas went to the wet scrubber. The wet scrubber was a tall, narrow metal cylinder that spanned the two floors of the gas house. Inside the wet scrubber, there were a series of levels through which the gas rose. At each level, a layer of cobblestones and a water spray cleaned the gas. The wet scrubber removed any solid particles in the gas, particles that were probably sulphur, silica or other waste products of coal.[26]

The dry scrubber was the next destination for the gas. Placed just outside the building on a platform, this short, wide cylindrical tank was filled with coke. This scrubber further cleaned the gas by taking out any remaining impurities the wet scrubber had missed.[27] In contemporary handbooks and texts on gas production, the wet and dry scrubber were often combined into one process with water spraying over layers of coke; the D,L & W consequently differed from standard practice by dividing the cleaning tasks into two processes.[28]

From the dry scrubber, the gas was sent to a 10,000-cubic-foot holding tank outside the building. The gas was stored in this gas holder until it was drawn off for use in the furnaces and forges of the locomotive shops.[29] Like the steam pipes coming in from the power house, most of the gas pipes to the shops were sent through the extensive subway system of the complex.[30]

Estimates vary on the exact chemical composition of the water gas made by the D,L & W plant, but a typical "recipe" would include 50 per cent hydrogen and 40 per cent carbon monoxide. These two flammable gases compose the majority of water gas. The invisible, poisonous carbon monoxide is the major ingredient not only in water gas, but in other related producer gases as well. (The other producer gases are made in virtually the same process, except that air, instead of steam, is used in the gas-producing blast.[31]) Both hydrogen and carbon monoxide give a pale blue light when burned; consequently this type of pure water gas is often referred to as "blue water gas".[32] In addition to the hydrogen and carbon monoxide, water gas contained small percentages of nitrogen (N) and carbon dioxide (CO_2). The objective in water gas production was to keep the nitrogen (from the air) and carbon dioxide (from the air, or incomplete reactions) to a minimum. The last components of water gas were trace amounts of hydrocarbons.[33] These components, formed by a separate reaction between the hydrogen and carbon, were not particularly useful for the purposes of the D,L & W. In much larger amounts, these hydrocarbons, such as methane (CH_4) could be used as illuminants. Sometimes, the water gas process included a carburetor stage to add hydrocarbons (from petroleum) to the gas. The D,L & W gas house clearly did not have this carburetor, and so it is reasonable to conclude that the water gas produced there would have been incapable of providing illumination.[34] In fact, in a contemporary specific analysis of D,L & W gas, the author claimed low percentages of nitrogen and CO_2 and no quantities of hydrocarbons.[35]

In terms of energy or heat, one cubic foot of blue water gas could release about 300 BTUs of energy.[36] This can be compared to 130 BTUs in air-blasted producer gas, 540 BTUs in carbureted water gas and 950-1100 BTUs in natural gas.[37] The relative energy inefficiency of blue water gas was balanced by an economic efficiency because of the D,L & W's access to anthracite, as discussed above.

With its two generators the D,L & W gas house could produce anywhere between 300,000 cubic feet to 1,200,000 cubic feet of gas per day, with 950,000 cubic feet being the average output. Each generator was put through twenty-two to twenty-four runs per day (with a "run" consisting of one steam blast/air blast cycle). One ton of coal could generate about 66,500 cubic feet of water gas. When in operation, the locomotive shops consumed 1,200-1,800 cubic feet of gas per minute.[38]

The generators were generally shut down at night. The ashes, 800-1,000 pounds, were cleaned out, placed on a conveyor that carried them back up to the railroad track, and removed from the site in hopper cars. The fire was allowed to die down, but not to extinguish as shutting down and starting up the generators was not efficient. The author of a 1912 journal article speculated that the whole operation would be more efficient if the plant was run twenty-four hours a day, but this would necessitate more gas-holder space to store the gas during the night when the locomotive shops were not consuming any gas.[39] By 1920, there was a second gasholder of 15,000 cubic feet to supplement the first, but it is unclear if this addition prompted round the clock gas production.[40]

NOTES

1."Water Gas Replaces Oil For Furnaces," American Engineer Vol. 86, No. 1 (January 1912), 27.

2."Water Gas," 33.

3.L.B. Lent, "Producer and Water Gas for Furnaces," American Machinist Vol. 33, Part 2 (December 8, 1910), 1058.

4.Lent, 1058; and N. Berkowitz, An Introduction to Coal Technology (New York: Academic Press, 1979), 253-254.

5.Lent, 1058.

6.Oskar Nagel, The Mechanical Appliances of the Chemical and Metallurgical Industries (New York: Oskar Nagel, 1908), 187.

7."Water Gas," 31.

8."Water Gas," 31.

9."Water Gas," 31.

10.George L. Fowles, "Scranton Shops of the D, L & W," Railway Age Gazette Vol. 47, No. 19 (November 5, 1909), 868.

11."Water Gas," 31.

12."Water Gas," 35.

13.Geoffrey Martin, et al., Industrial and Manufacturing Chemistry, Part II: Inorganic, 6th edition, Vol. I (New York: Philosophical Library, Inc., 1955), 126.

14.Martin, 127.

15."Water Gas," 31.

16.Martin, 127.

17.Delaware, Lackawanna and Western Railroad, Proposed Additional 10' X 15' Gas Generator At the Gas House of the Locomotive Shops, Scranton, Pennsylvania, December 28, 1915, (plan), Steamtown National Historic Site, Scranton, Pennsylvania.

18."Water Gas," 35.

19.Ada Louise Huxtable, "Concrete Technology: Historical Survey," Progressive Architecture (October 1960), 147.

20.Railway Age, November 14, 1922, 705; and "New Delaware, Lackawanna & Western Specifications for Portland Cement," Railway Age Gazette, Vol. 54, No. 4, 158-159.

21.Delaware, Lackawanna and Western Railroad Company, Scranton Locomotive Shops: Gas House, February 4, 1909, (plan), private collection of John Willever.

22.D,L & W, Gas House, (plan); and "A Modern Locomotive Repair Plant," Railway World Vol. 53, No.36 (September 3, 1909), 739.

23.Martin, 131.

24."Water Gas," 30.

25.Martin, 131.

26. "Water Gas", 29; Martin, 137.

27."Water Gas," 29.

28.Lent, 1060.

29."Water Gas," 29.

30."A Modern Locomotive", 740.

31.M. Popovich and Carl Hering, Fuels and Lubricants (New York: John Wiley and Sons, Inc), 41-42.

32.Martin, 127.

33.Popovich, 42.

34.Martin, 134; and A.J. Johnson, Fuels and Combustion Handbook (New York: McGraw-Hill, 1951), 265.

35."Water Gas," 30.

36.N. Berkowitz, An Introduction to Coal Technology (New York: Academic Press, 1979), 254.

37. Johnson, 261; Martin, 89.

38."Water Gas," 30.

39."Water Gas," 30.

40.D,L & W, <u>Gas House</u>, (plan).

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